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Vol. 13, Communication 274. (Owen; A Provisional Classification of Malayan Soils)

THE JOURNAL OF THE RUBBER RESEARCH INSTITUTE OF MALAYA

JULY 1951

Issued by
The Rubber Research Institute of Malaya

Reprinted from The Journal of Soil Science, Vol. II, No. 1.

Price 50 Cents.

PUBLICATION NOTE

This paper entitled "Provisional Classification of Malayan Soils" was published in The Journal of Soil Science Volume II Number 1 January 1951. By agreement with the Editor of the Journal and by the courtesy of the Clarendon Press, Oxford, offprints of the paper have been supplied to the Rubber Research Institute for distribution in Communication form. With this acknowledgement Mr. Owen's paper on Malayan Soils now appears as Communication No. 274 in the Journal of the Rubber Research Institute.

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A PROVISIONAL CLASSIFICATION OF MALAYAN SOILS

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WITH PLATES I TO 3

Synopsis

A scheme for classifying Malayan soils is suggested tentatively, based on general observations at irregular intervals over a number of years, and not on a continuous detailed study of the characteristics and distribution of individual soil types. No schematic mapping has been done, but the soils chosen for sampling and analysis are representative of the most important soil groups.

The main factor on which the soil series are differentiated is soil parent material. The parent materials are classified broadly and the soils derived from these are described briefly. Tentative suggestions are made for the nomenclature of the soil series classified.

The soils are described mainly on the basis of morphological characteristics. A few analytical data are included. Brief reference is made to the potentialities of the soils judged chiefly on growth of rubber-trees. Views are expressed regarding the suitability of some of the more important soils for cultivation of other crops.

The relationship of Malayan soils to the recognized 'great soil groups' is discussed briefly.

Introductory

A DETAILED survey of Malayan soils has never been carried out and it is fully realized that, until this is done, any attempt at classifying the soils must be regarded as tentative. Where information is limited, approximations are often useful and it is perhaps desirable to record relevant observations even though they are admittedly inadequate to effect a complete system of classification of all Malayan soils. These observations have been made at irregular intervals over a number of years when opportunities arose to visit rubber estates in all parts of the country, not specifically for the purpose of classifying the soils on those estates, but chiefly to advise on problems relating to rubber cultivation and to conduct field experiments.

Geography and Climate

Malaya is part of the peninsula which extends southwards from Burma to Singapore. The distance from the northernmost boundary at Perlis to the southern tip at Singapore (latitude 1° 18′ N.) is about 700 miles and the country covers an area of about 51,000 square miles. Along the western and eastern sides of the peninsula are extensive alluvial plains extending inland for varying distances up to a maximum of 40 miles in the western plains and about 20 miles on the eastern side. From the coastal alluvial plains the country rises gradually through an intermediate band of foothills, which are extensively developed agriculturally, to a series of jungle-clad high mountain ranges running north and south, with valley troughs where agricultural development has proceeded more slowly.

Mean temperature and rainfall vary but little from year to year, and records for the year 1947 are given as an indication of the climatic conditions. Mean rainfall for the year was 110 in., with a minimum of 83 in. on the west coast and rising to a maximum of 169 on the east coast. The mean temperature was 80·7° F. with the limited range of 79·5° to 82·3° F. for ten stations; the mean maximum was 88·0° F. and the mean minimum temperature was 73·3° F. (Meteorological records for the hill stations, i.e. Fraser's Hill and Cameron Highlands, have not been included.)

*Geology**

The geological structure of Malaya is complex, but the main features may be summarized briefly as follows. Granite and other non-volcanic igneous rocks cover about half the total area. While most of the high mountain ranges are predominantly granitic, the range which includes the highest mountain (Gunong Tahan) is a notable exception, being composed mainly of upper Paleozoic or Mesozoic sedimentary rocks. The sedimentary rocks older than the granite occupy roughly a third of the total area. The major proportion of the remainder is covered with alluvium. Rocks younger than the granite are limited to very small areas of Tertiary sedimentary rocks.

The greater proportion of the developed land in Malaya is probably composed of soils derived from the sedimentary rocks older than the granite. Since these rocks must occupy an important place in any discussion of local soils, a synopsis of the lithological variation within this large group is given. They comprise:

(i) Triassic Formation: quartzite, shale, phyllite, schist with some chert and conglomerate.
(ii) Carboniferous and (?) Permian Formations: limestone, shale, phyllite, schist with some chert and quartzite.
(iii) Pahang Volcanic Series: Predominantly pyroclastic rocks with some lavas.

A little more than three-quarters of the surface of Malaya is covered with jungle or uncontrolled indigenous vegetation of one kind or another. Of the total area alienated for buildings, for agricultural development, and as mining land, more than half is planted with *Hevea*. It will be seen, therefore, that although observations recorded herein refer mainly to rubber land, they cover an appreciable proportion of the total area which must include soils derived from most of the important rock formations of the country. Soils derived from a few of the less important rock formations known to occur have not been located.

Basis for Soil Classification

A primary requisite in attempting to classify soils is to determine a suitable basis for classification. To this end we may consider which of the factors of soil genesis play the most important role in determining the morphological differences observed in the soil profile. The principal

* The writer wishes to acknowledge his indebtedness to the various publications of the Geological Survey Department, Federation of Malaya.

genetic factors are: climate, relief, parent material, time, and vegetation. The relative importance of each of these factors depends upon the scope and the purpose of classification. When considering the higher categories of classification of the soils of the world or a continent, climate and vegetation assume major importance, but over a small land area such as Malaya these genetic factors are fairly uniform. We are concerned here with establishing lower category units based on physical and chemical properties of the soils themselves, and the dominant factors which determine local variations in profile characteristics are relief, parent material, and time. Of these, parent material is undoubtedly the most important genetic factor and the most suitable basis for classification of local soils.

Some Malayan soils have been described and classified by Dennett (1929, 1932, 1933), Wilshaw (1932), and Hamilton (1936). Dennett (1929) recognized distinctions between soils formed from different parent materials but was content to classify parent materials into four main groups as follows: granite, quartzite, Raub family, and alluvium. Later on he (1933) adheres to the same broad classification, but to this list he adds the Highland Soils as well as those derived from the pyroclastic rocks of the Pahang Volcanic Series, and from dolerite. In attempting to subdivide these large groups, which are essentially based on a broad classification of geological formations, Dennett attaches more importance to the effect of topographical relief than to the effect of complex lithological variations within the broad geological groups he recognizes. In referring to the soils of the Raub family he distinguishes high-level soils and low-level soils; the so-called quartzite soils are subdivided into valley quartzites and general quartzites, while granitic soils are similarly separated into hill and valley soils.

The use of the terms 'Raub family' and 'Quartzite' for the parent materials of soils derived from rocks of the Carboniferous group and of the Triassic group respectively is unfortunate. Both terms suggest that the soil's parent material in each case has a fairly uniform mineralogical composition, or that the rocks included in each of the groups are lithologically similar. On the contrary, the soils which are included in each of the two groups are derived from a variety of rocks with widely different lithological characteristics. The name 'Raub Series' was first used by Scrivenor (1931) when he referred to the calcareous shales and allied rocks which are prevalent in the district around the Raub Australian Gold Mines. Later Scrivenor admits that it was a mistake to adopt this name and it was discarded. But the main objection to the use of the name in soil classification is that it may convey an erroneous indication of the nature of the parent material. The soils included are not calcareous nor are they necessarily derived from calcareous shales.

The use of the term 'Quartzite' in the sense that Dennett (1929, 1932), and later Hamilton (1936), used it is equally unfortunate, and perhaps even more so because the misuse of the name has gained currency in Malaya. One hears frequent reference to a quartzite soil when the soil may be derived from shale, phyllite, or schist. On sifting the evidence it would appear that the name 'Quartzite' has been used for all phases of the Triassic group of rock formation. The so-called quartzite soils

described in the literature cited are those derived from a complex variety of rocks recognized by the geologist as falling within the Triassic group. Quartzite forms one of the lithological variations, and as a parent material of soils is probably the least important. Of the soil types which fall within this group, the most widely distributed are those derived from shales, phyllites, schists, and sandstones. It is pertinent to note that quartzite nearly always weathers back into sandstone under the moist tropical conditions prevailing in this country.

Hamilton (1936) disposes of the soil parent materials under the headings granite, quartzite, limestone, Pahang Volcanic series, coastal deposits, and alluvium. Referring to granite soils he points out the difference between virgin and cultivated soils, but otherwise makes no distinction between types. Regarding the soils which he classes as quartzite soils, he appreciates that the rocks from which they are derived are very variable, so it is evident that he has in mind not only quartzite but other diverse beds forming the Triassic rocks; the use of the name 'quartzite' is therefore misleading. Hamilton discards the term 'Raub Series' but he substitutes the name 'limestone' when he evidently means rocks of the Carboniferous group. Soils derived from limestones cover relatively small areas in Malaya but soils derived from other quite distinct lithological variations of the Carboniferous group are widespread and are economically much more important.

The principle of using the parent material as a basis for classifying the soils has been accepted, but it is evident that previous workers in this field have adhered too rigidly to the broad classification of the geological formations as given in published geological maps, ignoring the complex lithological variations within each group which are clearly recognized in the field and are described in the memoirs published by the Geological Survey Department Federation of Malaya.

Parent Materials of Malayan Soils

The soil parent materials may conveniently be listed in the order of geological age, thus showing the possible variations within each geological age group as indicated on the published geological maps of Malaya.

Recent sediments. Alluvial deposits may be divided into two main groups: coastal deposits and inland alluvium. The coastal deposits consist principally of heavy clays and peat. The heavy clays of the western coastal belt form a distinct soil type quite different from the soils formed from inland alluvium. There are minor variations in texture and composition of the clay fraction, but for purposes of classification they are sufficiently uniform to justify grouping these together as one soil series. The writer is less familiar with the alluvial deposits on the east coast, but it is evident that the soils are more variable, sandy deposits occurring more frequently and covering larger areas in this region than in the west. It would seem, however, that the heavier soils of the east coast are similar to those in the western coastal belt, but pending further investigation they are regarded as a separate soil series.

Peat occurs as a deposit of variable depth over clay. In virgin jungle areas of the coastal belt the heavy alluvial clay is invariably covered by a layer of peat, varying in depth from a few inches to several feet. Development of such land for agricultural purposes results in exposure of this organic horizon, which then shrinks and is gradually extenuated by oxidative decomposition. Where the original peat horizon is shallow it disappears in course of time, so the existence of a transitional group of soils consisting of shallow peat over clay must be recognized. Areas of peat, several feet in thickness, do occur, however, but these have not been studied in detail.

Inland alluvium is much more variable than, and easily distinguished from, the coastal alluvial deposits. The former occurs at a slightly higher elevation and covers relatively large areas in the extensively developed intermediate belt between the coastal flats and the steeply rising terrain running along the centre of the peninsula. It covers, in particular, much of the area west of the Main Range where solid geology is shown on the geological maps as Carboniferous, and it contributes largely to the agriculturally developed land in parts of Perak and Selangor.

At this stage our knowledge of the inland alluvial deposits permits only for a classification of the soils into three main groups: (1) soils developed under conditions of impeded drainage; (2) free-drainage soils, loams, and clay loams with good permeability; (3) sands and sandy loams where drainage is excessive. Each of the three groups is regarded tentatively as one soil series but considerable variability is recognized, allowing for subdivision into several soil types.

Soils derived from recent deposits are classified as follows:

Parent material			*Soil series*	*Drainage*
Recent sediments	Coast deposits	Peat	Unclassified	Impeded
		Clay	1. Selangor Series (west coast)	Impeded
			2. Kelantan Series (east coast)	Impeded
		Sands	Sungei Buloh Series	Excessive
	Inland alluvium	Clays, loams	1. Perak Series	Impeded
			2. Chemor Series	Free

All soils developed on sandy deposits, whether they occur as lenticles in the coastal clay area or as part of the more irregularly distributed riverine alluvium, are provisionally classified as one group pending more detailed examination.

Igneous rocks (*post-granite, granite, and pre-granite*). The various soils derived from igneous rocks are widely different, depending on whether the parent material is basic or acidic. Soils derived from acid igneous rocks cover large areas in all parts of the country, while those derived from basic rocks are limited in extent, occurring locally in a few widely separated regions.

The group of acid igneous rocks consists of plutonic types, mainly granite, and volcanic types (andesites, rhyolites, &c.). Granite occurs over very large areas in all parts of the country and soils derived from granitic rocks probably cover a larger area in the aggregate than any

other soil. It is recognized that the solid formation varies considerably in mineralogical composition, but the final product of weathering appears to be fairly uniform, apart from variations in texture and the coarseness of the quartz grains. The coarse sand fraction is composed almost entirely of quartz. At this stage two soil series are recognized, one derived from fine- and medium-grained parent material (Rengam Series) and a less fertile, paler coloured soil derived from the coarse-grained phase of the granite (Tampin Series). The former is economically more important since it covers the major proportion of the total area of soils derived from granite.

Little is known about the soils derived from andesite, rhyolite, and other acid volcanic rocks since it happens that they do not occur to any great extent in the areas opened up for development. They are included in the classification because they are known to occur and are probably widely distributed in the jungle areas of Pahang and Kelantan.

Soils derived from basic igneous rocks, although limited in extent, are of particular interest and importance because they are the most fertile of all the sedentary soils in Malaya. Soils derived from the plutonic types of basic rocks have not been identified, but gabbro has been located in a few isolated areas by the geologists and a more detailed survey of the country will no doubt reveal the existence of more extensive outcrops of these rocks. Therefore provision has been made in this classification for including soils derived from plutonic types of basic rocks. Soils derived from volcanic types of basic rocks have been identified and examined. The largest consolidated area occurs in east Pahang. Here the soil is derived from basalt and has been provisionally named the Kuantan Series. In north Johore a deep friable red soil, derived from a basaltic lava, occurs over an area of several hundred acres. This is morphologically different from the Kuantan Series, and one is easily distinguished from the other by colour, texture, and structure. Chemical composition of the clay fraction also reveals differences between the soils. Performance on the two soils is equally good in so far as this can be determined from growth and yield of rubber-trees, but recognition of two soil series is justified on the basis of morphological characteristics.

Malayan soils derived from igneous rocks, therefore, are classified as follows:

Parent material			*Soil series*	*Drainage*
Igneous rocks	Acid rocks	Plutonic types (mainly granite)	1. Rengam Series	Free
			2. Tampin Series	Free
		Volcanic types (andesites, rhyolites, &c.)	Unclassified	
	Basic rocks	Plutonic types (e.g. gabbro)	Unclassified	
		Volcanic types (mostly basaltic)	1. Kuantan Series	Free
			2. Segamat Series	Free

Non-calcareous rocks of Triassic and Carboniferous age. For purposes of soil classification these two geological age groups are classified as one unit because a similar petrological sequence occurs in both groups. The non-calcareous formations of both Triassic and Carboniferous ages in

Malaya consist of sandstones, shales, phyllites, and schists. Soils derived from corresponding beds of Triassic and of Carboniferous ages are indistinguishable from each other; thus a soil derived from argillaceous rocks which fall in an area mapped by the geologist as Trias appears to be identical with a soil derived from shale of Carboniferous age. In this classification of local soils reference will be made to soil parent materials as sandstones, argillaceous rocks, and schists irrespective of whether they are of Triassic or Carboniferous age. Triassic rocks also include some coarse conglomerates. Soils derived from these are known to occur over limited areas, but these have not been examined. Provision is made in this classification for including soils derived from conglomerates.

In the published geological maps of Malaya the Trias formation is described briefly as consisting of quartzite and shale (a more detailed petrological description in the published literature includes phyllites, schists, and conglomerate). The omission of quartzite as a soil parent material needs explanation, especially since the term 'quartzite soil' has gained currency in Malaya. As a first step in the process of weathering in this country quartzite usually weathers back into a sandstone. Where quartzite occurs the solid strata immediately below the soil are usually sandstones. It seems logical therefore to regard the parent material of that soil as sandstone rather than quartzite.

The soils included in this section are probably more familiar to the casual observer than any of the other soils since they cover the major portion of the gently undulating terrain which lies between the coastal flats on the west and the steeply rising ground farther inland, a terrain which has been highly developed agriculturally and over which most of the major roads pass. In spite of easier facilities for examining these soils due to accessibility, considerable difficulties in classifying the soils have been presented by the complex variation, the interbedding of the solid formations, and the consequent merging of the products of weathering. Soils derived from essentially Triassic rocks and from lithologically similar beds of the Triassic and Carboniferous groups of rocks are classified tentatively as follows:

Parent materials		*Soil series*	*Drainage*
Trias and Carboniferous (non-calcareous rocks)	Conglomerates	Unclassified	..
	Sandstones	Kedah Series	Free
	Argillaceous rocks (shales, phyllites)	1. Batu Anam Series	Slightly impeded
		2. Malacca Series	Free
	Schists	Seremban Series	Slightly impeded

Calcareous rocks. Calcareous rocks consist of calcareous shales and limestones. The former lose their calcite by weathering, so presumably the soils derived from these would be indistinguishable from those derived from non-calcareous shales. No soil known to be derived from calcareous shales has been identified locally, and since it is unlikely that the calcareous nature of the parent rock would be perceptible in the final product of weathering, the soil being derived from the siliceous

portion of the rock, there seems little justification in recognizing these shales as a soil parent material different from the non-calcareous shales.

Limestone outcrops in several places, but it occurs usually as small hills rising abruptly from the plains. Soils derived from limestone are confined to a few yards around the base of these picturesque masses of pure limestone rising almost perpendicularly to an appreciable height above the general level of the surrounding country. The soils cover only a relatively small area in the aggregate, but, although not always suitable for rubber cultivation, they are very fertile and are particularly suitable for crops which can tolerate neutral and alkaline conditions. The soils examined are fairly uniform, varying slightly in intensity of red colour and reaction. They are grouped together provisionally as one soil series —the Perlis Series.

The classification of the parent materials of Malayan soils and the disposition of the various soils derived from these are summarized in the appendix. Inevitably there are a number of omissions. No doubt a more systematic survey of the soils will reveal a number of types which have not yet been identified, but there are others which have been observed and noted; because they are abnormal types which occur locally in relatively small areas, they have not been included in the classification. The occurrence of transitional soils of mixed origin on contacts of schist-granite and granite-limestone, &c., such as those described by Wilshaw (1932) for instance, is recognized, but they cover limited areas and are relatively unimportant. It may be of interest to report that podzolic soils have been located here, with morphological characteristics similar to those of the podzols in temperate countries. They have developed on light porous sands of alluvial origin, usually in depressions or on flat sandy terraces. In Malaya they are of academic interest rather than of agricultural importance.

Description of the Soil Series

Peat. Peat and peaty soils have not been studied in detail and no differentiation into soil series has been attempted on account of insufficient data. They occur in irregularly dispersed patches in the low-lying coastal alluvial expanse both on the west and the east coasts. In their natural state they are almost continuously submerged, and deep drainage is essential for successful development of peat areas for agricultural purposes. Rubber-trees grow well in these areas provided drainage is adequate, but difficulties have been experienced when rubber is planted on land which has been newly opened up. Not infrequently young rubber plants become moribund, or their rate of growth is severely retarded a few months after planting when their roots reach the water-logged horizon where toxic compounds are formed under the reducing conditions which exist. Symptoms of toxicity are more in evidence in areas where the peat is deep and where waterlogging occurs in the organic layer. When opening up virgin peat land it is sometimes advisable to cultivate shallow-rooting food crops for a few years as a preliminary to the establishment of the deeper rooting tree crops to allow for shrinkage and consolidation of the peat and to give time for a more thorough

investigation of drainage possibilities. In some areas at least this has been a customary procedure. It is of interest to note that Chinese squatters in peat areas often burn the surface horizon of peat as a preliminary to cultivation of food crops. This is done before the land is drained so that the depth of burning is controlled.

Although rubber-trees grow well on artificially drained peat, the yield of rubber per acre is seldom as high as that on the freely drained mineral soils. Moreover, the surface level of the peat is continuously being lowered, not only as a result of shrinkage due to progressively more effective elimination of surplus water, but also due to oxidative decomposition at the surface. Sooner or later the roots of trees are exposed. At best the root system is confined to a relatively shallow horizon and, with such a limited root hold, leaning trees are a common feature on peat land. The leaf canopy is usually heavy, which is to be expected on this type of land, so it is inevitable that appreciable losses of trees during wind storms do occur. No doubt peat areas are being exploited more successfully and to a better purpose when utilized for cultivation of shallow rooting economic crops.

Coastal alluvial soils. Alluvial soils are separated into two main groups generally referred to briefly as coastal alluvial clays and inland alluvial soils. The morphological characteristics of the former group of soils are fairly uniform although minor local variations are recognized. For instance, occasionally one comes across small patches, generally not more than a few acres in any one place, where a horizon of soil mixed with fragments of sea-shells occurs at, or close to, the surface, probably indicating an old beach. This horizon is seldom more than about 12 in. in thickness, but naturally it affects performance because of the marked difference in reaction of the medium. There are textural variations which must be recognized too, but over the major proportion of the flat coastal belt on the west coast the soil is a silty clay varying in colour from dark brown to blue-grey, depending on the amount of organic matter and on the level of the water-table. A typical sequence of colours in a soil profile is as follows: dark brown on the surface, brownish-grey immediately below followed by a horizon of brownish-grey silty clay with yellow and rusty mottlings, which in turn changes into blue-grey silty clay at lower levels. This permanently wet blue-grey horizon is very acid, and a pH of less than 3 is not uncommon. This brief description applies to the soils over the greater part of the coastal alluvial belt on the west coast, allowing for variations in depth and compactness of the different horizons. The name Selangor Series is tentatively suggested for this group of soils.

Less information is available regarding the soils of the east coast, but judging from general observations it would appear that sandy deposits form a much greater proportion of coastal alluvium in the east than in the west. However, the heavier soils developed under conditions of impeded drainage do cover quite large areas on the east coast as well, and they appear to have many characteristics in common with the Selangor Series. Until they have been examined in more detail, however, they are provisionally classified as a separate series for which the name Kelantan Series is proposed.

Soils of the Selangor Series are, potentially, the most productive soils of the country. With suitably controlled drainage and judicious management they grow most crops. When covered with vegetation they develop a fairly porous structure in the upper horizons in spite of their heavy nature, and this good structure is not impaired on exposure so quickly as that of the inland sedentary soils. Compared with other Malayan soils these heavy coastal alluvial soils have large reserves of plant nutrients. The contents of nitrogen and potash are high and available phosphate values, as determined by standard methods of analysis, are invariably higher than corresponding values for the inland sedentary soils, although low judging by the standards of soils of temperate countries. Little or no response to applications of fertilizers in experiments in young and mature areas of rubber on these soils has been detected. Nutrient deficiency is seldom a limiting factor to growth of rubber on the Selangor Series. Performance is determined almost invariably by the extent to which drainage conditions can be improved, but it is seldom possible to lower the permanent water-table sufficiently to achieve optimum conditions for rubber cultivation. The trees are usually very well grown, it is true, and carry dense green foliage, but the yield of rubber per unit area is invariably lower on these soils than on the freely drained inland soils. There is no doubt that these coastal alluvial soils are more suitable for shallow-rooting crops, and, if extension of land for food production is ever contemplated to cater for the needs of an increasing population, the possible development of these flat coastal areas for more intensive cultivation with food crops merits careful consideration. Here are large areas of highly productive soils which, with careful management, are capable of producing good crops for many years without resort to fallow resting to restore structure and fertility.

Cultivation of food crops in tropical soils is a special problem which is outside the scope of the writer's work and therefore cannot be discussed in detail, but it is a problem which no one who is interested in the potentialities of the soils can afford to ignore. The possibility of inter-cropping food crops in rubber areas has been considered from time to time and arising out of this problem the suitability of different soil types for cultivation of short-term food crops has been considered. The effects of cultivation of crops which give inadequate protection to the soil are well known. Loss of soil by erosion is the most serious factor, but the principles of soil conservation methods are well known; with careful management, the harmful effect of erosion can be reduced considerably, although measures taken are seldom completely effective. What is often not fully realized is that tropical soils deteriorate on exposure even though loss of soil by erosion is prevented. The organic matter in the surface soil is soon lost by oxidation and the structure of the soil is rapidly impaired, both of which result in a lower status of fertility. The harmful effects of erosion, oxidation, and loss of structure become apparent more quickly when the soil is mechanically disturbed by digging or ploughing. Some soils deteriorate more quickly than others. Of the local soils, those derived from schists are probably the worst in this respect and are the least suitable for cultivation of food

crops, especially those crops the harvesting of which entails mechanical disturbance of soil. Soils derived from argillaceous rocks (shales and phyllites) also deteriorate fairly rapidly on exposure. Granitic soils are intermediate, while the most stable of the inland soils are those derived from basic rocks. The latter are eminently suitable for cultivation of food crops provided effective measures are taken to control erosion. Unfortunately these soils cover a relatively small area and cannot contribute much to any scheme for large-scale food production. If the other inland soils were utilized for continuous cultivation of food crops, provision would have to be made for reafforestation within a few years to restore structure and fertility. The re-establishment of forest growth may take several years unless a rotational system of cropping is followed, designed so as to prevent the establishment of lalang (*Imperata arundinaceae*) as an ecological sequence in the change from cultivation of economic crops to forest fallow. This might be possible if the rotation ends with the cultivation of a vigorous tree crop.

Taking all factors into consideration, it would seem that the coastal alluvial flats would be the most suitable for intensive cultivation of food crops if the need for this should become urgent. The area available is large, the soils are fertile, water is abundant and, with suitable drainage, the supply can be controlled to suit most crops.

Inland alluvial soils. Inland alluvium is of mixed origin and consequently the soils developed on this transported material are very variable. Detailed classification of these mixed deposits has not been attempted, but three main groups may be recognized: (1) soils developed under conditions of impeded drainage; (2) free-drainage soils, loams, and clay loams with good permeability; (3) sands and sandy loams where drainage is excessive. The first two groups resemble the inland sedentary soils rather than the coastal alluvial soils. Morphological characteristics of the first group are similar to those of soils derived *in situ* from argillaceous rocks, while soils of the second group are comparable to the sedentary soils derived from more arenaceous rocks. In performance, and in response to manuring also, they resemble the inland sedentary soils rather than the coastal alluvial soils.

Alluvial sands are in a class apart. They have quite distinct morphological characteristics and are in no way similar to the reddish-yellow soils derived *in situ* from sandstones. These sandy alluvial sediments, whether they form part of the large expanse of marine alluvium or of the more scattered areas of inland alluvium, are provisionally grouped together as one soil series.

Soils developed under conditions of impeded drainage are silty clay loams, the colour of the surface horizon is mainly grey with yellow mottlings. This lies over blue-grey silty clay loam at varying depths below the surface. These soils are lighter in texture and generally less impervious than the coastal alluvial silty clays (Selangor Series). Artificial drainage is essential for successful cultivation of most crops, especially rubber, although not to the extent that this is necessary on the lower lying and heavier soils originating from marine alluvium. Topography varies from flat to very gently undulating. Rubber-trees grow well

on these soils provided drainage is adequate. Nitrogen and potash contents are medium to medium-high, while phosphate content is invariably very low. Rubber-trees on these soils usually respond to manuring. Ironstone concretions in the solum are not common, although they do occur occasionally, distributed irregularly in small pockets or as a thin band at varying depths below the surface. The name Perak Series is tentatively suggested for these soils.

Free drainage soils of alluvial origin are yellow to reddish-yellow in colour, varying in texture from sandy loams to clay loams; laterite concretions are usually absent. They resemble the more widely distributed freely drained sedentary inland soils and for purposes of making recommendations for manuring of rubber-trees they are classed together. Nitrogen content is low to medium, phosphate content is invariably low, and potash content is variable. These soils are provisionally called the Chemor Series.

Bedded sands and sandy gravel transported by streams form terraces which are drier and on a higher level than the more recent alluvium. The soils developed on these sandy deposits vary from coarse-grained loamy sand to fine-grained sandy loam. Drainage is excessive. Growth of rubber usually reflects a low status of fertility and response to manuring is generally well marked. Nitrogen, phosphate, and potash contents are very low, and treatment with a complete fertilizer is usually recommended at all stages of growth of the rubber-trees. These soils are provisionally grouped together as one series—the Sungei Buloh Series.

There is evidence to suggest that most of these alluvial sands are podzolic in character. In a few areas one or all of the A_0, A_1, and A_2 horizons are clearly seen, changing into compact brownish-yellow light sand (B horizon) at lower levels. In one place a thin layer of cemented and lustrous iron oxide on top of the B horizon was clearly observed. These are abnormalities, however, since they occur only in very small patches and, locally, they are of little importance agriculturally. The majority of these loose sandy soils show no clearly defined zonation apart from a darkening of the surface 2 or 3 in. by organic matter. Then it changes abruptly into pale yellow or pale brownish-yellow sandy material often with irregularly distributed patches of more compact, dark brown or ferruginous coloured sand. The yellow horizon, with or without the dark brown patches, is usually deep, reaching to a depth of 5 ft. and often deeper. The clay fraction separated from samples of one profile examined has a very low silica-sesquioxide ratio. Analytical data are shown in Table 1.

TABLE 1

Horizon	*Clay* %	*Organic carbon* %	*pH*	*Clay fraction* SiO_2/R_2O_3
0–3 in.	6·6	1·08	5·5	0·33
3–8 ,,	9·7	0·57	5·5	0·28
8–14 ,,	9·8	0·31	5·3	0·21
14–24 ,,	10·3	0·20	5·3	0·22

It is probable that this soil is the relict of an illuvial horizon, the eluvial layers having been lost by oxidation and erosion.

Soils derived from acid igneous rocks. Only soils derived from granitic rocks have been identified and examined. These cover very large areas in all parts of the country. Soils derived from volcanic types of acid rocks occur only in limited areas, at least in the developed parts of the country, but they may be more widely distributed in the jungle areas of Pahang and Kelantan where these volcanic rocks are best developed.

The depth to which granitic rocks weather varies considerably, but usually the soil is very deep. According to Scrivenor (1931) the average depth to which granite weathers is about 30 ft. 'Core-boulders' which resist weathering are common but seldom sufficiently abundant to interfere with the exploitation of the land. The high mountain ranges are predominantly granitic, but most of this area is too steep for cultivation. The gently sloping foothills, however, have been extensively developed.

The soils derived from granite are classified into two series. One of these, the Rengam Series, covers the major proportion of the total area of granitic soils. Soils of this series which are derived from fine- and medium-grained parent material are reddish-yellow, friable, sandy clay loams, often micaceous. Occasionally a gradual change from yellow to yellow with red mottling, and finally to a uniform pale red colour, can be observed within 6 ft. from the surface, but usually the uppermost reddish-yellow horizon is much deeper. The pale reddish hue at lower levels is typical of the product weathered from granite. Concretions of ironstone have not been observed in these soils.

The performance of the Rengam Series is good judging by the growth of the rubber-trees, and even in old rubber areas or in replanted areas severe physical deterioration of the soil is not apparent except that the surface soil has a tendency to pack and form a hard impermeable crust on exposure. Where structure and natural fertility of the soil have been impaired, it usually reflects the effect of previous cultivation with other crops, the planting and harvesting of which entailed frequent mechanical disturbance of the soil. Evidence of this is seen in several districts, particularly in parts of Negri Sembilan and Malacca where food and other short-term crops were extensively cultivated during the latter half of the last century in land which has since been planted with rubber-trees. Nevertheless, even in these previously cultivated areas the degree of deterioration is appreciably less in the granite soils than in those derived from argillaceous rocks and from schists.

As in most other inland soils, the nutrient status of the Rengam Series is by no means high. Nitrogen and phosphate contents are low while potash content is medium-low to medium. The better performance of the Rengam Series compared with some of the other inland soils reflects better physical condition rather than a more abundant reserve of nutrients. Texture and structure are good and the soil is deep, friable, and permeable, allowing for easy absorption and free movement of water. Rubber-trees on these soils respond to treatment with nitrogen and phosphate, but response to treatment with potash has not been demonstrated. It would appear that most of these granitic soils contain reserves

of potassium adequate for normal development of rubber-trees, much of which is probably present in the form of unweathered potassic minerals.

The second soil series recognized, the Tampin Series, is derived from coarse-grained highly siliceous granitic rocks. The soil is a coarse-grained sandy loam, whitish-grey at the surface changing into pale yellow below. A characteristic feature is the high proportion of very coarse sand consisting mainly of quartz with some mica. No laterite concretions have been observed. Drainage is free to excessive. The soil is clearly less fertile than the Rengam Series, and in performance it is only a little better than the sandy alluvial soils (Sungei Buloh Series). The Tampin Series covers relatively small areas and because of its limited distribution it has not been examined in detail. No manuring experiments have been sited on it, but it is expected that, like the Sungei Buloh Series, it will respond to regular and fairly frequent applications of a complete fertilizer.

Soils derived from basic igneous rocks. Only soils derived from volcanic types of basic igneous rocks have been identified and examined. Although limited in extent they are conspicuous, not only because of their rich, distinctive colours but also because of the luxuriant growth of crops planted on these soils. They are the most fertile of all inland soils in Malaya and it is to be hoped that much larger areas occur in the unexplored jungle land.

Two soil series are recognized, both of which are derived from basaltic parent material and are equally productive, but each of the two series has distinct morphological characteristics and one is easily distinguished from the other by colour, texture, and structure. Moreover, the chemical composition of the clay fractions of the two soil series is different.

The Kuantan Series, which is well represented in east Pahang, is a dark reddish-brown loam over clay loam, very friable and permeable, with a distinctive, fragmental structure. It is very deep, and to a considerable depth is uniform in colour, texture, and structure. Small laterite concretions may be distributed irregularly in the solum and sometimes a more or less continuous band of rounded concretionary ironstone may occur at lower levels. Roots of rubber-trees are well distributed throughout the profile to a depth of several feet, a feature which is not common for Malayan soils. Nutrient content is relatively high except for 'available' phosphate as determined by the Truog method which is low, but phosphate extracted by HCl (1 : 1) is high. Furthermore, the contents of nutrients fall with increasing depth below the surface much more gradually in this soil than in all other inland soils derived from acid and intermediate rocks. The composition of the clay fraction is different from that of all other soils examined in that percentage SiO_2 is exceptionally low ($\pm$10 per cent.) and percentage of Fe_2O_3 is exceptionally high (over 30 per cent.). It naturally follows that the silica-sesquioxide ratio is very low. Analytical data are shown in Table 2.

The Segamat Series, which has many characteristics in common with the Kuantan Series, is a deep brownish-red heavy clay, friable and permeable; it has a mildly developed crumb structure, contains no gravel or laterite concretions, and is uniform in colour and texture to at least

TABLE 2

Horizon	Clay %	Organic carbon %	pH	Clay fraction SiO_2/R_2O_3
0–3 in.	25·2	3·13	5·1	0·26
3–6 ,,	48·4	1·95	5·2	0·25
6–12 ,,	54·9	1·35	4·9	0·21
12–24 ,,	56·7	0·90	5·1	0·21

15 ft. Roots of rubber-trees are well distributed to a depth of about 6 ft. Performance on this soil is excellent; trees are very large and yields of rubber are generally high. Values for organic carbon and plant nutrients are comparable with those of the Kuantan Series except that the phosphate extracted by HCl (1 : 1) is even higher. Composition of the clay fraction, however, reflects certain fundamental differences between the two soil series. Percentage SiO_2 is much higher and percentage Fe_2O_3 much lower in the Segamat Series. Analytical data are shown in Table 3.

TABLE 3

Horizon	Clay %	Organic carbon %	pH	Clay fraction SiO_2/R_2O_3
0–3 in.	65·6	2·07	5·0	1·39
3–6 ,,	73·7	1·44	5·1	1·38
6–12 ,,	71·4	1·32	4·9	1·38
12–24 ,,	68·3	1·02	4·8	1·34

Soils derived from Triassic and Carboniferous sedimentary rocks

1. *Sandstones*. Soils derived from sandstones are reddish-yellow friable sandy loams, the depth of which varies depending on elevation and/or hardness of the underlying strata. Shallow soils, however, are not common; they are limited to the upper parts of the steeper hills where erosion has been active. The soil is a type which is easily eroded and is particularly unsuitable for crops the cultivation of which entails disturbance of, or gives inadequate cover to, the surface soil. This soil series may be classed as a good type exhibiting characteristics which are favourable for successful cultivation of rubber and other tree crops. The soil is loose and permeable, but drainage is not excessive. As in most other local soils, the clay content gradually increases with depth and the lower horizons are slightly more compact.

Analytical data for a soil derived from sandstone are shown in Table 4.

TABLE 4

Horizon	Clay %	Organic carbon %	pH	Clay fraction SiO_2/R_2O_3
0–4 in.	18·8	2·20	4·4	2·09
4–12 ,,	21·3	0·56	4·7	1·87
12–18 ,,	23·1	0·45	4·6	1·94

2. *Argillaceous rocks.* These include shales and phyllites. Two distinct soils series derived from these beds are classified (Batu Anam Series and Malacca Series), although it is realized that these may not include all the soil types developed under varying conditions on these argillaceous rocks. The shales show a fairly consistent type of weathering resulting in a fairly uniform product, but it is admitted that less is known about soil development over phyllites. It will be appreciated that identification of the parent materials of soils is often difficult in the tropics because of the great depth of weathering, especially of the softer rocks. However, these two parent materials are provisionally grouped together since there is evidence to show that both, under certain conditions, may give rise to soils which have many characteristics in common.

The Batu Anam Series is a soil which covers fairly large areas in all parts of the country on undulating and hilly land, but is best developed in strongly rolling country. Texture and colour vary within a restricted range, but in the main it is a yellow to brownish-yellow silty clay loam over mottled silty clay. At the top of the mottled horizon the dominant colour is yellow with darker yellow and grey mottling; as the partly weathered parent material is approached, grey becomes the dominant colour. Occasionally a narrow band (about 2 in.) of rounded concretionary laterite occurs at varying depths below the surface, but this is not a consistent feature of the soil profile. Fragments of quartz, the relict of a quartz vein in the parent rock, may also occur in the solum. Drainage is slightly impeded, but artificial drainage is never necessary. The soil is capable of good performance. Although compact, the upper part of the soil profile is fairly friable when covered with vegetation, and allows for easy penetration of roots, but it deteriorates rapidly on exposure. Rubber-trees on this soil usually respond to treatment with nitrogen and phosphate. Content of potash determined after extraction with HCl (1 : 1) is generally rather high, although values for exchangeable potash show considerably more variation. Analysis of the clay fraction indicates a feebly lateritic development. It is interesting to note the slight fall in the silica-sesquioxide ratio of the clay fraction of the horizon immediately below the narrow band of laterite. Analytical data are shown in Table 5.

TABLE 5

Horizon	*Clay* %	*Organic carbon* %	*pH*	*Clay fraction* SiO_2/R_2O_3
0–4 in.	31·3	1·84	5·2	2·68
4–12 „	38·7	0·53	4·5	2·08
12–24 „	47·9	0·27	4·5	2·19
24–26 „	Rounded concretionary laterite			
26–36 „	58·6	0·19	4·6	1·90

The Malacca Series occurs almost invariably on flat or very gently undulating terrain and usually at a lower elevation than the Batu Anam Series. This may be significant when considering the conditions favourable for the development of this particular soil type. A characteristic

feature of this soil series is the high percentage of ironstone or laterite. The proportion of gravel, which consists almost entirely of laterite concretions, may amount to 80 per cent. or more of the total weight of gravel plus matrix. The ironstone is also characteristic in that it is deposited as rounded but irregularly shaped concretionary gravel (globular concretions are not common) or occasionally as a hard slag-like mass. Both forms may occur together in the same area. The concretions vary in size up to about 1½ in. in diameter. The laterite horizon is loose at the top but more compact in the lower horizons. The matrix varies from a very friable yellow or brownish-yellow loam to a sticky reddish-yellow clay. The lower horizons show slight mottling, sometimes grey and sometimes bright reddish-brown. The laterite horizon is covered by a layer of friable yellow or brownish-yellow loam to clay loam free from gravel, varying in depth, but is seldom greater than about 12 in. Growth of rubber-trees is very variable, depending largely on the depth of soil above the laterite and on the mechanical composition of the matrix. Where the laterite concretions are loosely packed and the matrix is a friable loam, roots penetrate easily and are often well distributed to a depth of about 6 ft. In such areas a stand of well-grown trees may be established successfully, but performance generally is well below the standard for most other soils. Analytical data for a typical example of the heavier phase of the Malacca Series are shown in Table 6.

TABLE 6

Horizon	*Clay* %	*Organic carbon* %	*pH*	*Clay fraction* SiO_2/R_2O_3
0–7 in.	49·2	1·70	4·8	1·59
7–12 „	62·1	0·98	4·6	1·65
12–24 „	71·0	0·69	4·5	1·55
24–36 „	70·8	0·35	4·8	1·68

It has not been possible to ascertain with certainty the identity of the parent material of this soil. The evidence suggests that it is developed usually, but possibly not invariably, over phyllites. According to Scrivenor (1931) the greater part of the laterite in Malacca territory occurs over phyllites. Pending further investigations this laterite soil is classified as a soil derived from argillaceous rocks without further qualification, although the writer is of the opinion that soil in which the presence of laterite is a dominant feature is not likely to have developed over the shales.

3. *Soils derived from schists* show a number of minor variations, but since only a broad classification into units is intended, they are grouped as one series—the Seremban Series. The dominant characteristics of the soils are sufficiently uniform to justify this, but the minor variations are not entirely ignored and allowance is made for subdivision into soil types.

Schists weather into a soft mass in which foliation is preserved and frequently observed on examination of the lower horizons of the soil

profile. Immediately above this partly weathered parent material are fragments of ironstone or laterite having the same flattened structure. It would seem that these fragments have been formed in the incompletely weathered zone by displacement of the rock minerals by iron, retaining at first the original foliated structure of the rock and gradually increasing in thickness by further deposition of iron to form the roughly flattened ironstone fragments usually associated with soil derived from schists. Whatever the mode of formation of the laterite in this soil, the shape and structure of the fragments are characteristic of the soil type and quite distinct from the rounded concretions in the Malacca Series. Size and texture of the solid fragments, as well as their position relative to the surface, are extremely variable. A feature of the Seremban Series is the presence of quartz veins, often disintegrated and partly decomposed, which again are found at variable depths. Colour and texture of the soil vary within a restricted range, but yellow is the dominant colour and usually the soil is a sandy clay loam or sandy clay over clay. The clay horizon immediately below the ironstone fragments is frequently pale grey with rusty-brown mottlings. The upper part of the solum is friable and permeable while the clay below is sticky and impervious. Where this soil has been under cultivation for several years, there is ample evidence of severe erosion in the past and the present surface soil is doubtless exposed subsoil. The heavier phase of this soil series exhibits signs of impeded drainage close to the surface as a result of deterioration after cultivation and exposure. Performance is naturally very variable, depending largely on previous history of cultivation. In the virgin state it exhibits no unfavourable characteristic, and is capable of good performance provided its natural structure and permeability can be maintained. It is a soil which deteriorates rapidly on exposure.

Some analytical data for a typical example of the Seremban Series are shown in Table 7.

TABLE 7

Horizon	*Clay* %	*Organic carbon* %	*pH*	*Clay fraction* SiO_2/R_2O_3
0–3 in.	23·7	1·37	4·8	1·72
3–9 „	27·9	0·74	4·7	1·84
9–21 „	34·3	0·37	4·7	1·82

Soils derived from limestone. These soils are of very limited extent; they occur over a restricted area, seldom more than a few hundred yards in width, around the base of limestone cliffs in Selangor, Perak, and Perlis. The soil, provisionally called the Perlis Series, is a very friable dark reddish-brown loam over more compact clay loam. Colour is uniform to a considerable depth. No laterite concretions have been observed in the soil profiles examined. The soil is very fertile; the pH ranges from 6 to about 8·5, and the more alkaline phase of this soil series is not suitable for the cultivation of rubber. Nutrient status is comparatively high, although the content of readily available phosphate

(determined by the Truog method) is invariably low. Some analytical data for a soil derived from limestone are shown in Table 8.

TABLE 8

Horizon	*Clay* %	*Organic carbon* %	*pH*	*Clay fraction* SiO_2/R_2O_3
0–3 in.	21·2	2·28	6·2	0·63
3–6 „	22·6	1·28	6·1	0·62
6–12 „	26·8	0·88	6·1	0·61
12–24 „	24·8	0·75	6·2	0·60

Relationship to 'Great Soil Groups'

It is of interest to consider how the local soils, which we have grouped into lower category units, could be arranged into higher categories—the 'great soil groups'. Several systems of classifying world soils into higher category units have been proposed. The scheme outlined by Marbut and developed by the United States Soil Survey workers appears to be the most acceptable. This is based on the concept of zonality, showing relationships existing between soils and the climatic and ecological environments under which they have developed. A further elaboration of this scheme for classifying soils of tropical and equatorial regions has been suggested recently by Kellogg and Davol (1949). Consideration of the characteristics of Malayan soils leads to the conclusion that these are similar or very closely related to typical examples of the categories Kellogg and Davol describe, and it would appear that the major soil types of Malaya could be grouped conveniently in the higher categories of classification which they propose. It is considered that Malayan soils would fall within the following categories:

1. Zonal Soils	Reddish-brown Latosols	Kuantan Series
		Segamat Series
		Perlis Series (?)
	Yellow Latosols	Rengam Series
		Tampin Series
		Seremban Series
		Batu Anam Series (?)
	Yellow Podzolic	Sungei Buloh Series
2. Intrazonal Soils	Ground Water Laterite	Malacca Series
	Wiesenböden (?)	Selangor Series
3. Azonal Soils	Alluvial Soils	Perak Series
		Chemor Series

Latosols. Kellogg suggests this new term for soils which he describes as 'having their dominant characteristics associated with low silica-sesquioxide ratios of clay fraction, low base exchange capacities, low activities of the clay, low content of most primary minerals, low content of soluble constituents and a relatively high degree of aggregate stability'. These soils are lateritic in the sense that lateritization is in progress and an immaturely developed laterite horizon may be found in the profile, but they are distinguished from laterite soils in that the presence of a

laterite horizon is not a dominant feature nor is it an essential characteristic.

The majority of Malayan soils fall in this group. Those derived from basic rocks have characteristics which fit in with those classified as Reddish-brown Latosols. They are porous clay loams varying in colour from a rich brownish-red to reddish-brown; they have a well-defined structure, some fragmentary and others crumbly. In some of these soils a narrow band of concretionary laterite occurs at varying depths below the surface.

Soils derived from the more acid and siliceous rocks have a high proportion of yellow in the colour pattern. Typical colours are reddish-yellow (7·5 YR 6/8),* brownish-yellow (10 YR 6/6), yellow-brown (10 YR 5/4), and pale yellow (5 Y 7/3). They have all the essential characteristics of latosols and may be classified as Yellow Latosols. Their physical and chemical properties suggest close resemblance to the soils of the Belgian Congo described by Kellogg except that Malayan soils have even a lower content of soluble constituents and are probably less productive. The Yellow Latosols of Malaya appear to have a higher proportion of yellow in the colour pattern than the corresponding soils of Belgian Congo. This may be due to the fact that the former have been developed under more humid conditions (mean annual rainfall about 110 inches) or because they have been derived from more acid or more siliceous parent materials.

Ground Water Laterite. Accepting that the term 'laterite' should be confined to the materials which consist of hard concretions of iron and aluminium oxides, or slag-like masses, or softer ferruginous-bauxitic material which hardens on exposure, and accepting also that the term 'laterite soils' should be confined to those in which the presence of laterite is an essential and dominant feature, only one of the soil series recognized (the Malacca Series) can be classed as a laterite soil. The evidence suggests, however, that in most cases the laterite has been formed under the influence of a fluctuating water-table. Soils of the Malacca Series have developed usually, although possibly not invariably, over argillaceous rocks, and this implies the existence of an impervious horizon at the lower levels. It may be significant to note that these soils are found almost exclusively on flat or gently undulating ground at fairly low elevations. Furthermore, in most of the areas examined the lower horizons are distinctly mottled. Therefore it would appear that these soils have characteristics usually associated with Ground Water Laterites. In some areas evidence of a fluctuating water-table is absent within 6 ft. from the surface, although a similar deep horizon of indurated iron oxide has been formed, but one must assume that the typical mottling usually associated with a fluctuating water-table may occur at a much lower level. Nevertheless, the writer is not certain that a deep horizon of hardened laterite will not be formed except under the influence of a fluctuating water-table. Narrow bands of concretionary gravel are common and have been observed at varying depths below the surface in freely drained

* Symbols for hue, value, and chroma of colour according to the Munsell system of colour notation.

soils where the horizons above and below these bands of hardened laterite are identical in colour, texture, and structure, distinctly porous, and with no trace of any characteristic indicative of a fluctuating water-table. Even so, it is admitted that general observations lead one to the conclusion that laterite has developed in greater abundance either in, or immediately above, a medium in which water movement is or has been restricted, and may have been formed when the permanent water-table was much higher than it is now.

Alluvial soils. The character of the alluvial soils depends largely on their source and on local conditions of drainage and vegetation. The Selangor Series has well-developed characteristics reflecting the dominant influence of the nature of the parent material and drainage. Therefore it would seem that these may be classed as intrazonal hydromorphic soils rather than azonal soils. In the virgin state under forest they may have characteristics resembling Half Bog soils, but they are rapidly altered by cultivation, exposure, and the effect of artificial drainage. There are transitional soils in which a shallow dark brown peaty material overlies grey and mottled clay, but most of the soils included in the Selangor Series have a profile which appears to fit more closely the description given for Wiesenböden.

The inland alluvial soils have little profile development and it would seem that they may be classed as azonal soils.

Conclusion

The provisional character of the classification proposed cannot be too strongly emphasized. The suggestions put forward are not the outcome of a systematic survey of Malayan soils but of general observations made when opportunities arose to examine soils in several widely scattered places. The writer is fully conscious of many shortcomings and omissions. While parent material is undoubtedly the most important genetic factor in determining the characteristics of local soils, it is realized that the effect of relief is probably insufficiently emphasized. Also the effects of cultivation and erosion in altering the character of the soil profile have not been sufficiently stressed. Erosion has been prevalent, resulting in the production of truncated or immature soils. Until a detailed survey of the soils of the country is carried out the importance of these factors in determining the character of local soils cannot properly be assessed.

Acknowledgements

I wish to record my indebtedness to Mr. J. B. Alexander of the Geological Survey Department, Federation of Malaya, for helpful criticism of the proposal for classification of soil parent materials. My thanks are due also to my colleague Mr. C. G. Akhurst who has shared the work of sampling soils and has allowed me to make use of his profile descriptions. His co-operation and helpful suggestions are gratefully acknowledged.

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APPENDIX

Provisional Classification of Malayan Soils and their Parent Materials

	Parent material		*Provisional series name*	*Drainage*	*Remarks*
Recent Sediments	Coast Deposits	Peat	Unclassified	..	..
		Clay	1. Selangor Series	Impeded	Clays in the western coastal belt.
			2. Kelantan Series	„	Heavy soils of the eastern coastal belt.
		Sands	Sungei Buloh Series	Excessive	Includes lenticles of sand in the coastal alluvium as well as river-borne sands.
	Inland Alluvium	Clays and loams	1. Perak Series	Impeded	Soils developed under conditions of impeded drainage.
			2. Chemor Series	Free	Freely drained loams and clay loams. No laterite concretions. Relief flat or gently rolling.
Igneous Rocks	Acid Rocks	Plutonic types (mainly granite)	1. Rengam Series	Free	Soils derived from fine- and medium-grained rocks.
			2. Tampin Series	„	Soils derived from coarse-grained phase of granite rocks.
		Volcanic types, (andesites, rhyolites, &c.)	Unclassified	..	..
	Basic Rocks	Plutonic types (e.g. gabbro)	Unclassified	..	..
		Volcanic types (mostly basaltic)	1. Kuantan Series	Free	Reddish-brown soils. Highly ferruginous. Some laterite concretions in the lower horizons.
			2. Segamat Series	„	Brownish-red heavy clays derived from basaltic lava. No concretions.
Mesozoic and Upper Paleozoic Non-Calcareous Rocks	Conglomerates		Unclassified	..	..
	Sandstones		Kedah Series	Free	Reddish-yellow sandy loams. Relief undulating and hilly.
	Argillaceous Rocks (shales, phyllites)		1. Batu Anam Series	Slightly impeded	Yellow to brownish-yellow silty clay loams. Mottling at lower levels. Some laterite concretions.
			2. Malacca Series	Free	High proportion of rounded laterite concretions a dominant feature of these soils.
	Schists		Seremban Series	Slightly impeded	Sandy clay loams over silty clay. Flattened and platy lateritic fragments and a vein of quartz are characteristic features of these soils.
Upper Paleozoic Calcareous Rocks	Limestone		Perlis Series	Free	Dark reddish-brown clay.

(*Received 26 June 1950*)

1. Laterite soil near Sungei Buloh, Selangor. Profile showing laterite concretions. Surface as it appears after exposure for several weeks.

2. Laterite soil near Sungei Buloh, Selangor. Upper side of a terrace cut for planting rubber plants on sloping ground showing bed of concretionary laterite. Surface as it appears after exposure for several weeks.

3. Laterite soil near Sungei Buloh, Selangor. Profile exposed in a freshly dug pit. Laterite blocks dug out of the pit shown in top right-hand corner.